Status of phase defect printability studies in EIDEC

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Outline

1. Introduction
2. Defect models and phase defect printability simulation
3. Experimental of phase defect printability
4. EUV microscope and its image simulation
5. Summary

Introduction

Phase defect inspection technology development

2006 ~	2011 ~
MIRAI III (Selete)	**EIDEC**

Full field EUVL blank inspection prototype

- Commercial available DPP source
- Dark-field imaging
- TDI scanning mode
- Picture processing

Technology improvement

- Sensitivity improvement study
- **Phase defect printability study**
  - **Computer simulation**
  - **Exposure experiment using test mask**
  - **Mask observation technique**

HVM ABI prototype

- Throughput improvement
- Defect location accuracy

Tool available

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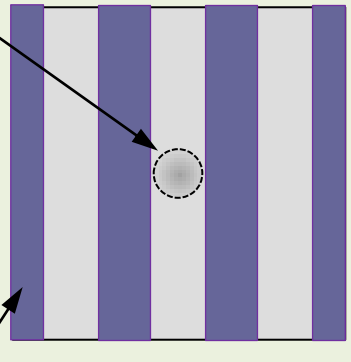
Image simulation

Mask pattern with phase defect

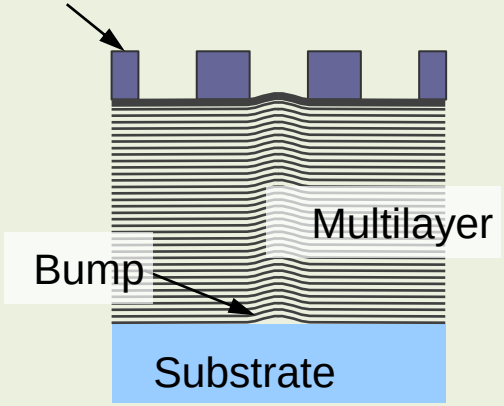
Exposure condition

Aerial image

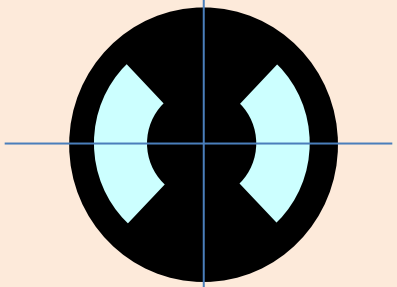
Phase defect



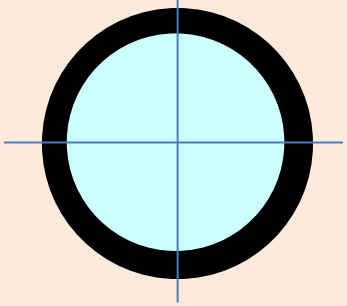
Absorber patterns



Dipole illumination, NA=0.25, 0.33

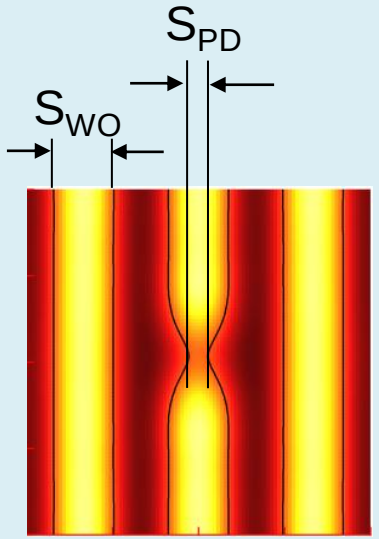


Circular illumination, NA=0.33

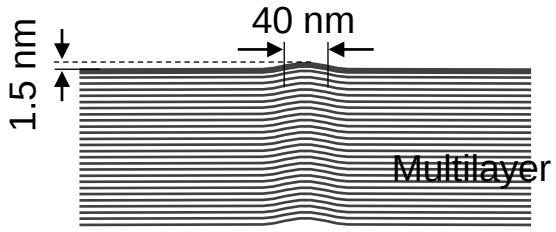
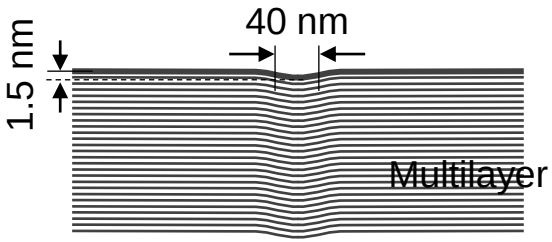
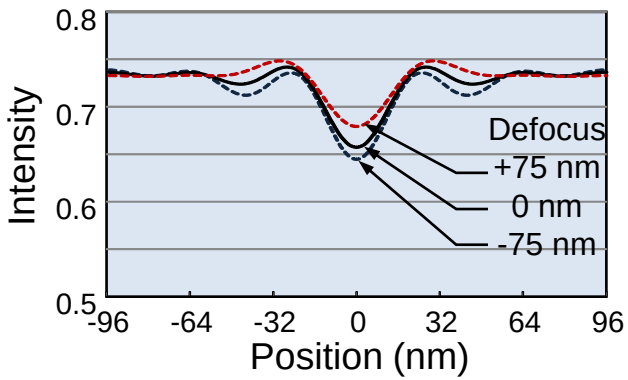
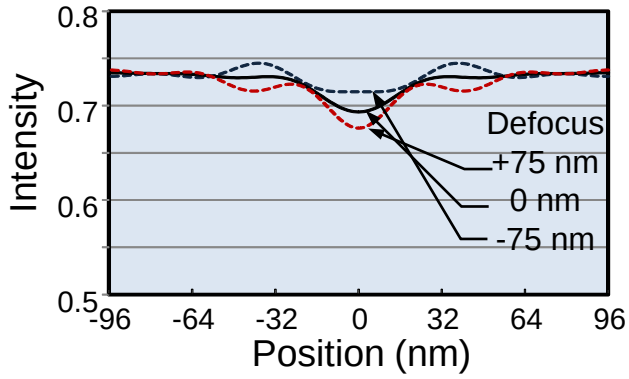
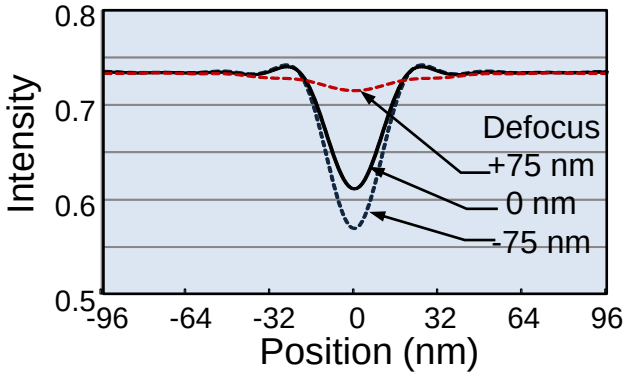
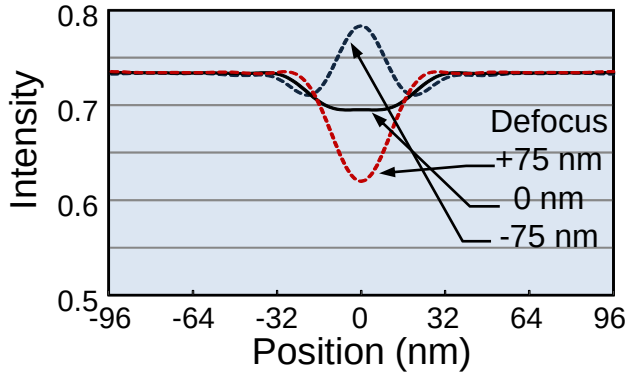


Space width error

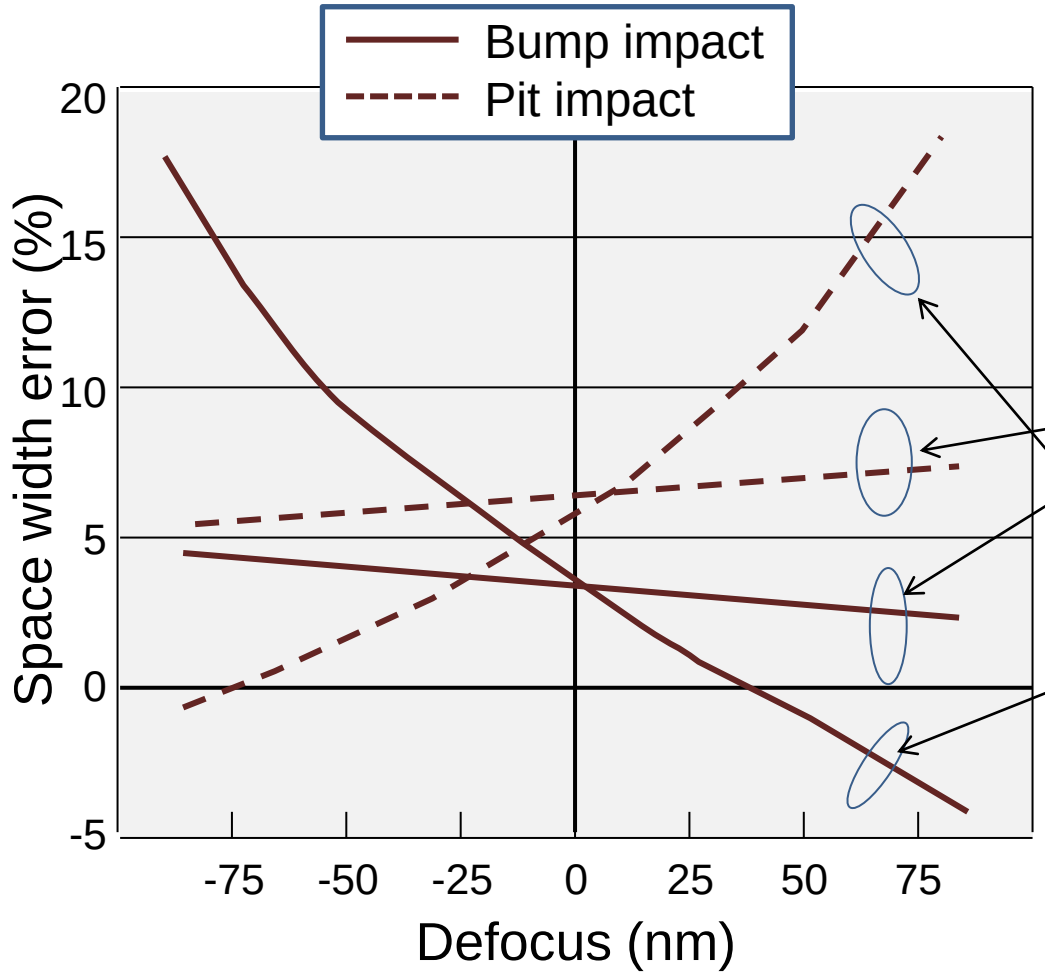
$$=100 \times \frac{(S_{WO} - S_{PD})}{S_{WO}} (\%)$$



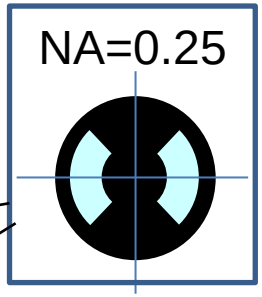
Phase defect image intensity

	Bump phase defect	Pit phase defect
Phase defect structure		
NA=0.25 Dipole illumination (Sigma=0.4/0.8, X-opening angle =90 deg.)		
NA=0.33 Circular illumination (Sigma=0.8)		

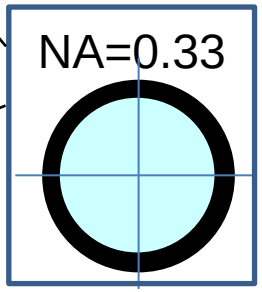
Simulated phase defect impact on 22nm L&S



Bump: W=50, H=1 nm
Pit : W=50, D=1 nm



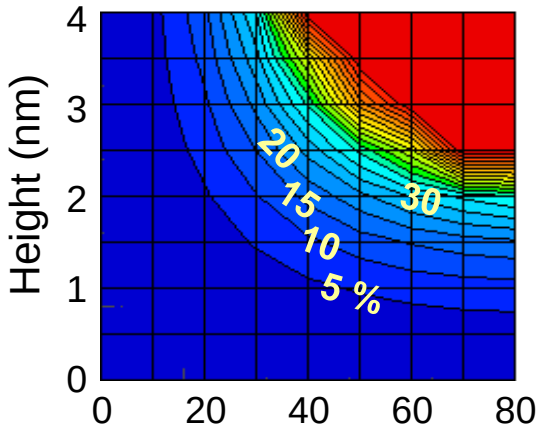
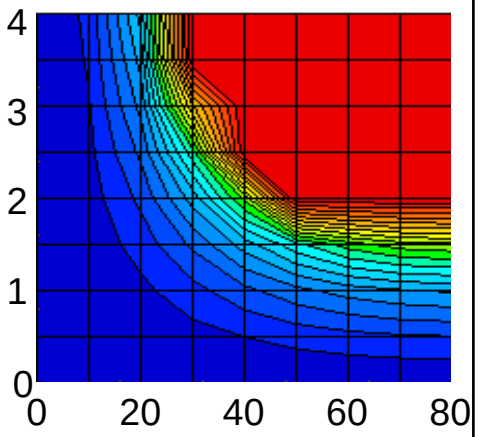
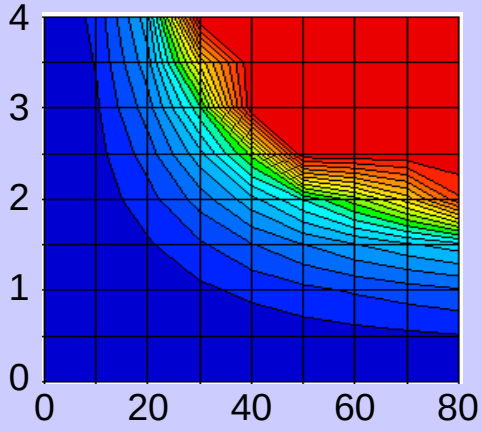
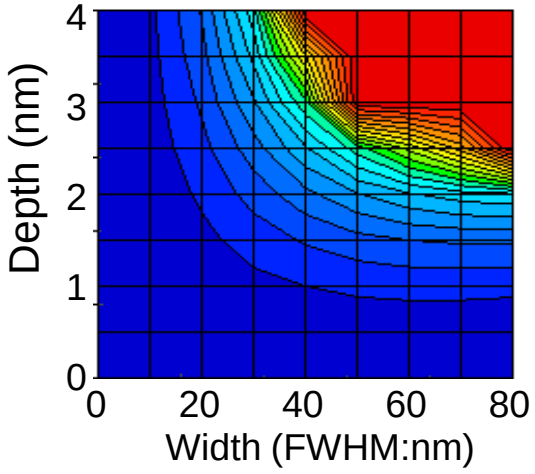
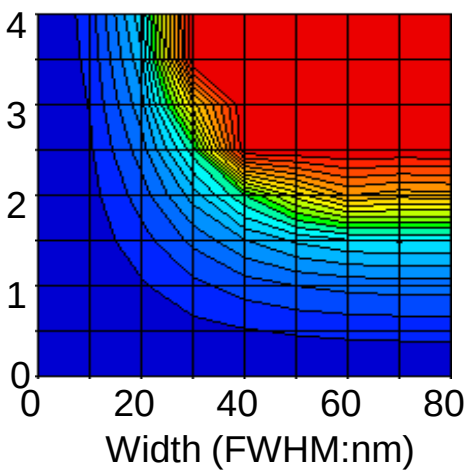
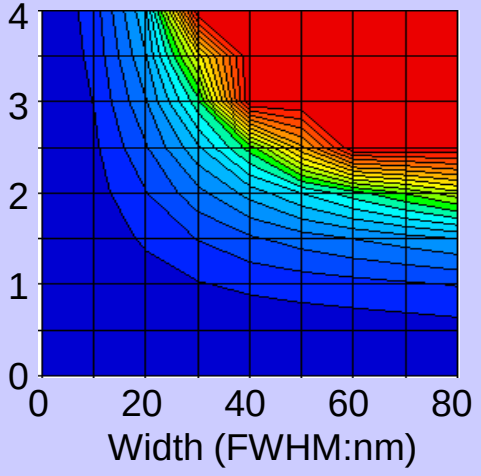
Dipole illumination
Sigma=0.4/0.8,
X-opening angle =90 deg.



Circular illumination
Sigma=0.8.

For dipole illumination, the pit defect impact at the positive defocus is stronger than the bump defect impact at the negative defocus.

Simulated space width error on 22 and 16 nm L&S

	22 nm L&S		16 nm L&S
	NA=0.25, Dipole illumination	NA=0.33 Circular illumination	NA=0.33 Dipole illumination
Bump phase defect (Defocus: -75 nm)			
Pit phase defect (Defocus: +75 nm)			

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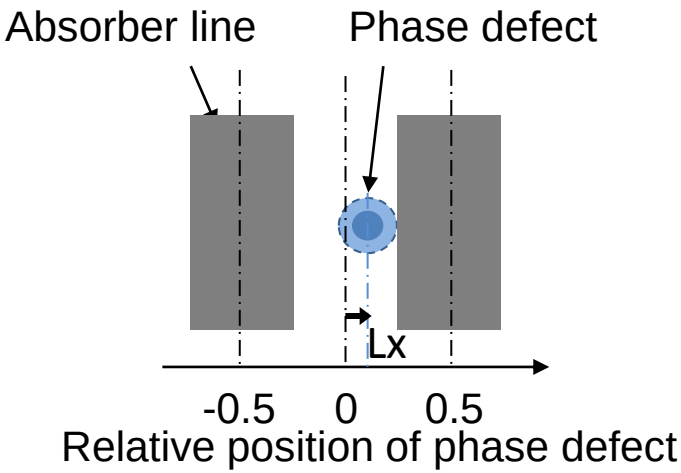
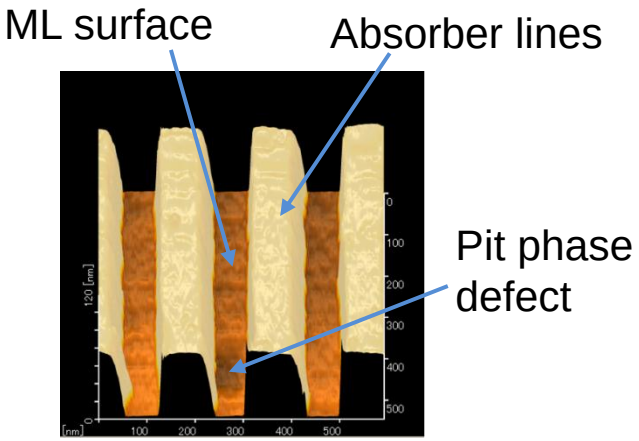
Experimental of phase defect printability

EUV Mask

- Absorber lines to print 26 ~ 22 nm L&S
- Pit phase defect of 100 nm ~ 40 nm in widths at mask



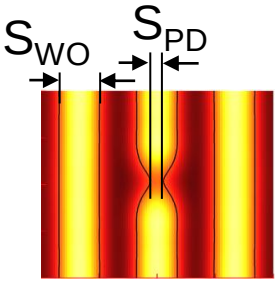


Exposure condition

- NA=0.25, Dipole illumination
- General resist process

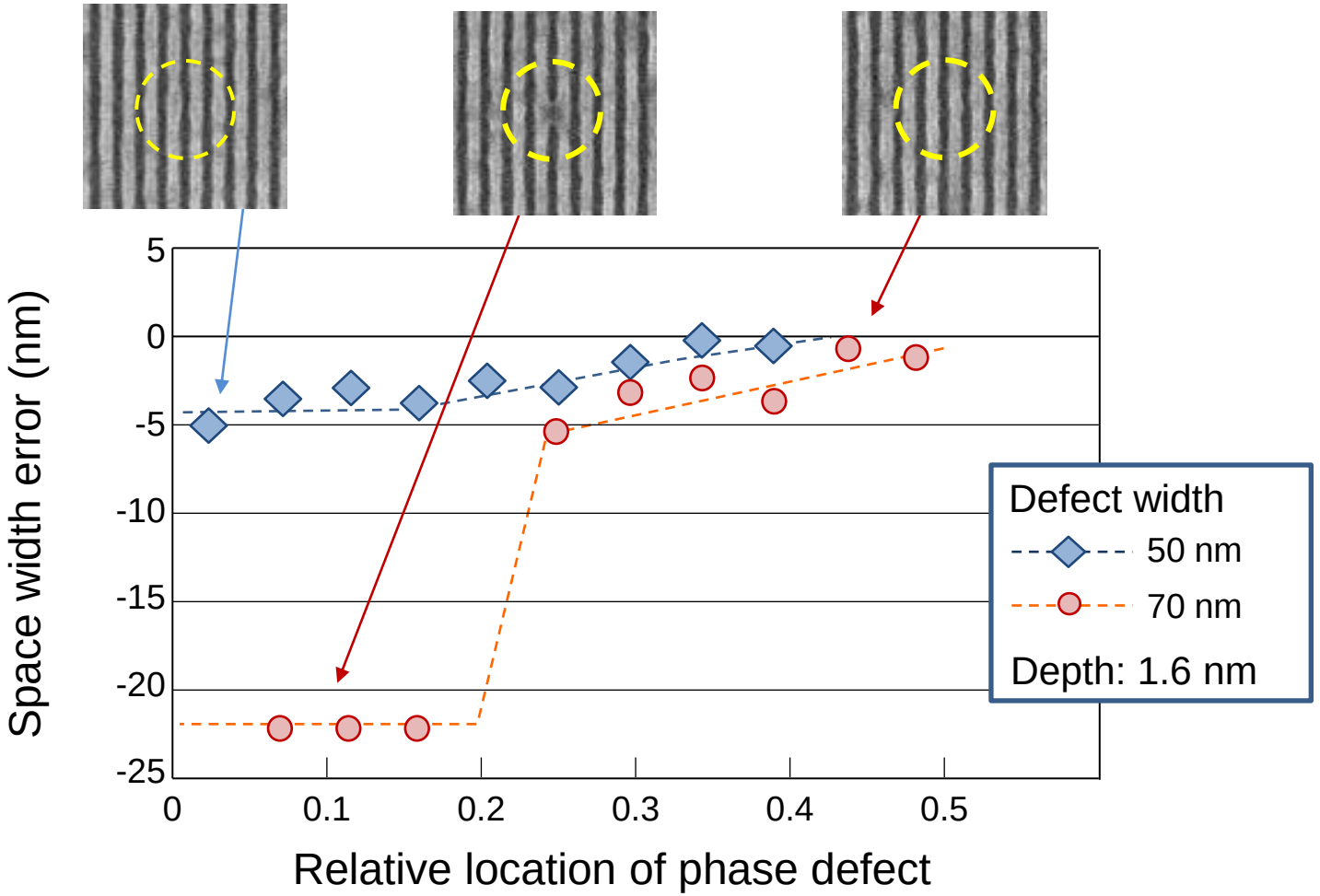
Evaluation

- Space width variation due to phase defect location



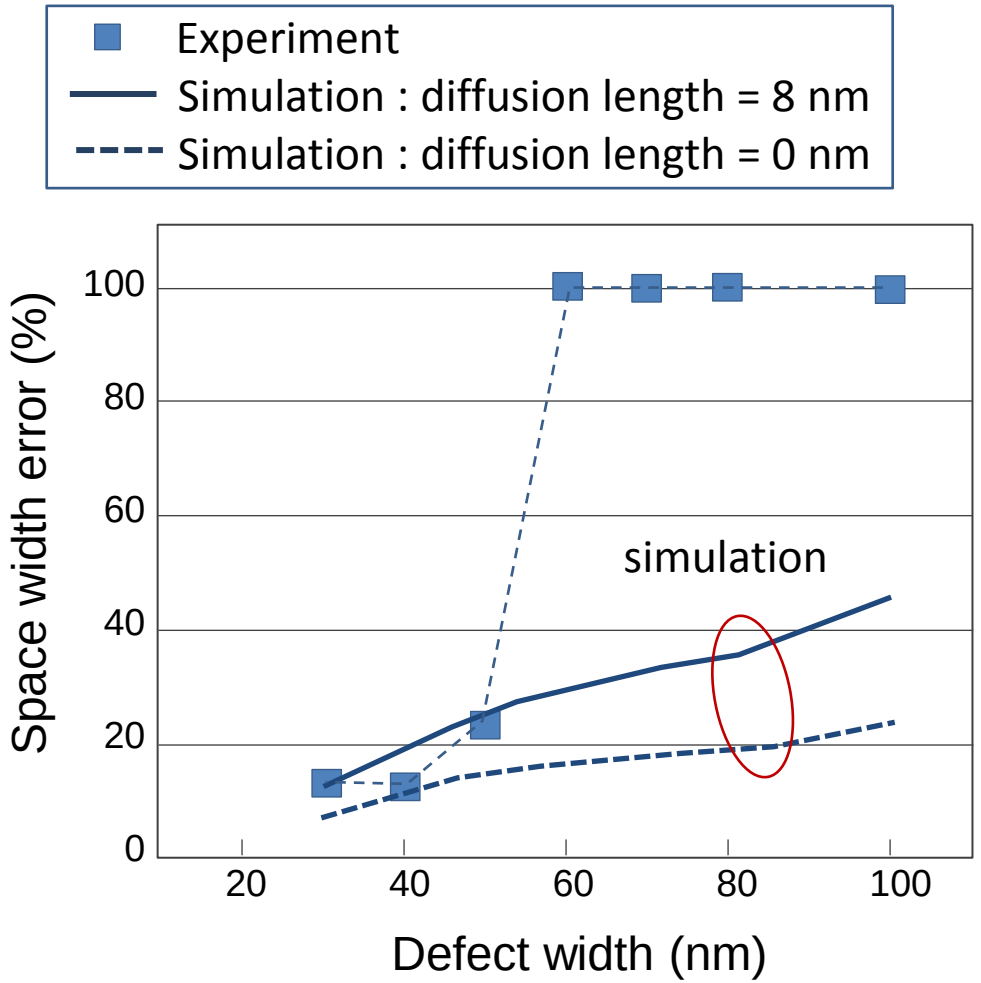
Space width error
= $S_{PD} - S_{WO}$

Defect location dependency: 22 nm L&S

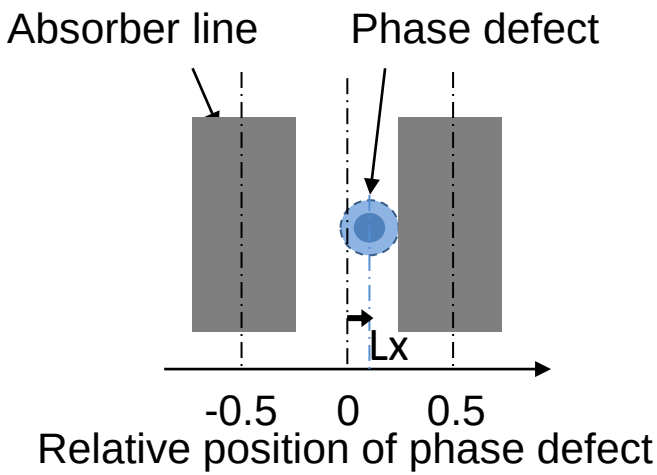


Measured space width varied depending not only on the phase defect but also on the LER of printed pattern.

Defect size dependency: 22 nm L&S

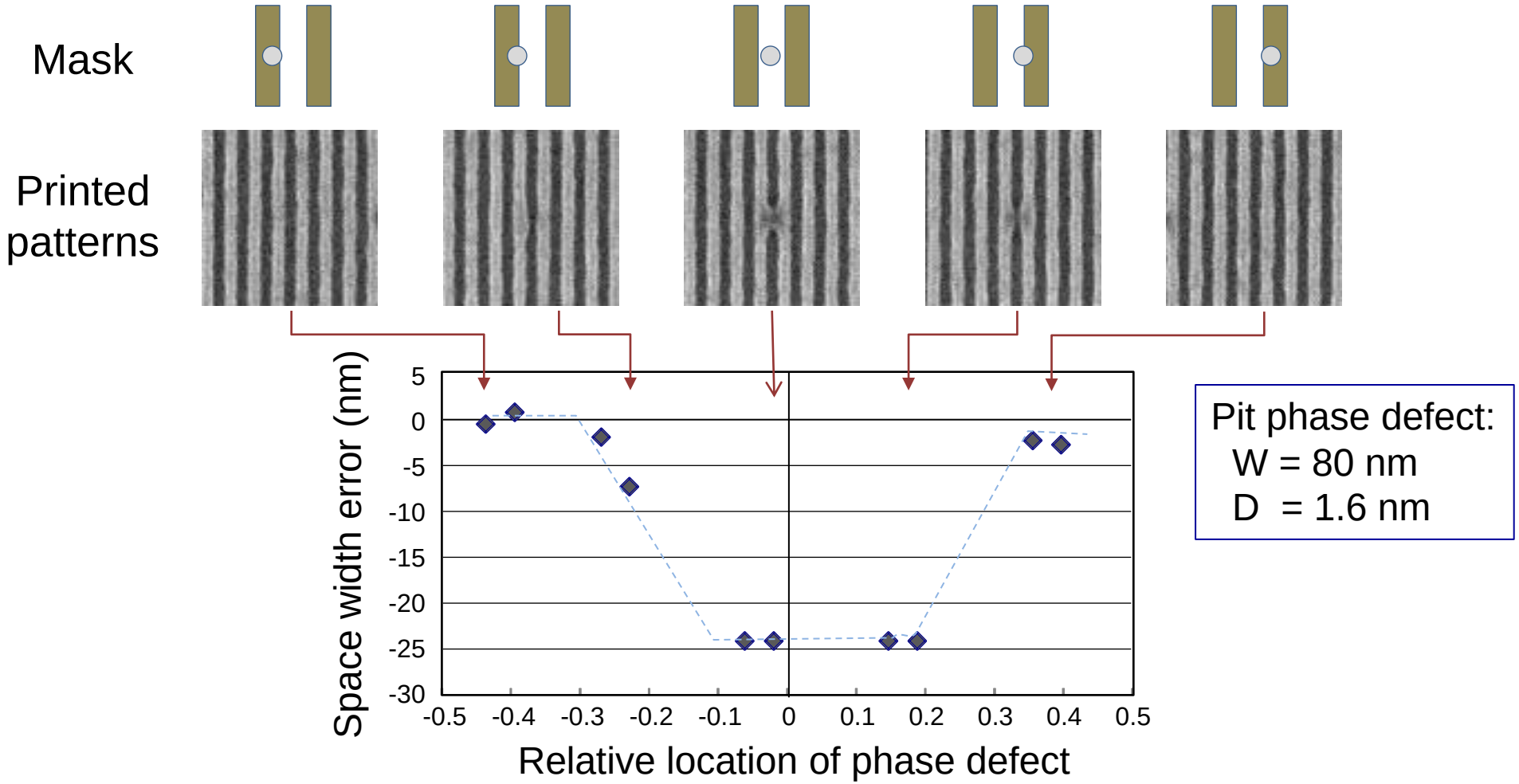


Relative position Lx
(-0.15 < Lx < 0.15)



Measured space width varied depending not only on the phase defect but also on the LER of printed pattern.

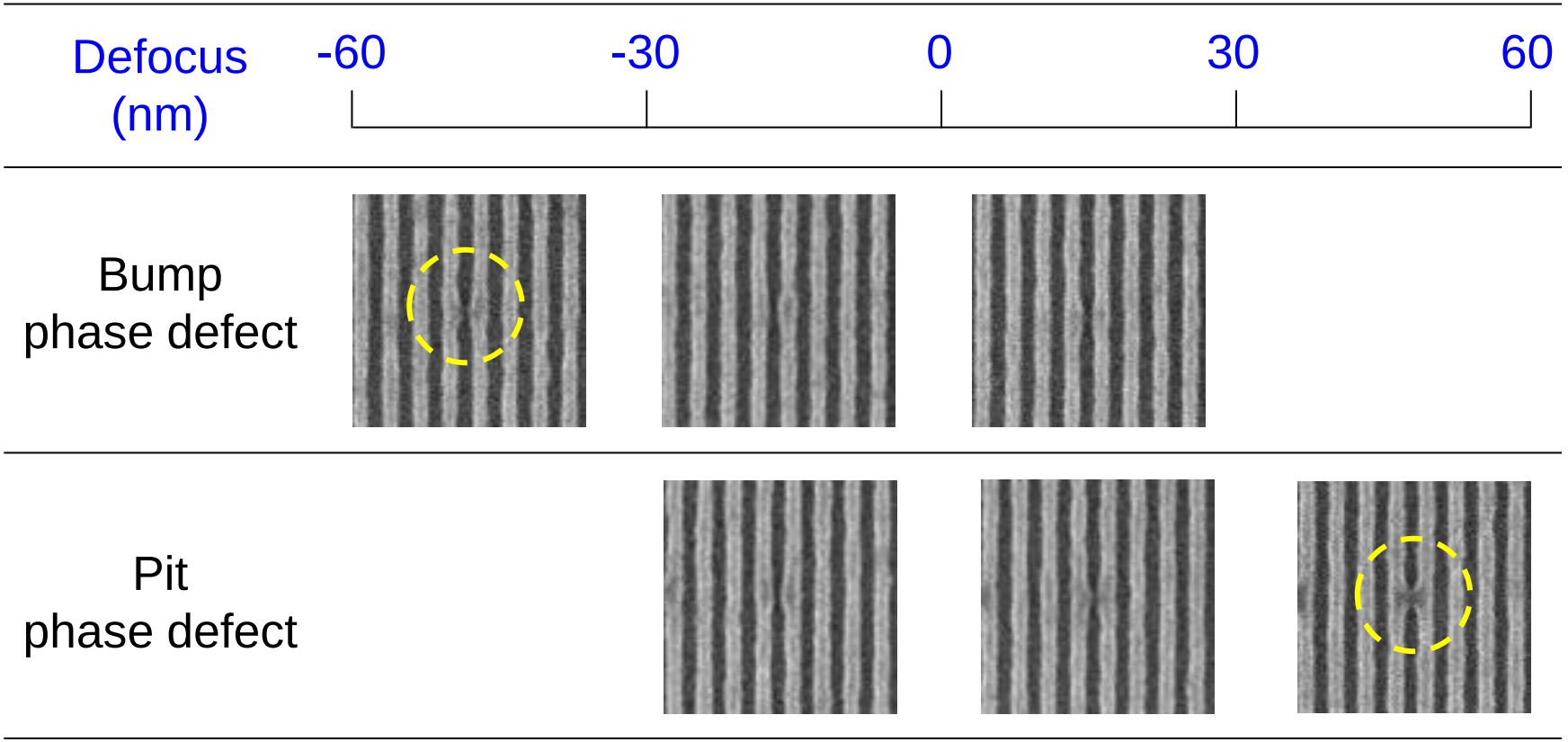
Defect location dependency: 24 nm L&S



Effectiveness of the phase defect mitigation by covering the defect with absorber patterns was experimentally confirmed.

Focus dependency

- Printed 26 nm L&S patterns on wafer
- Defect of 80 nm in width and 1.6 nm in height/depth at mask



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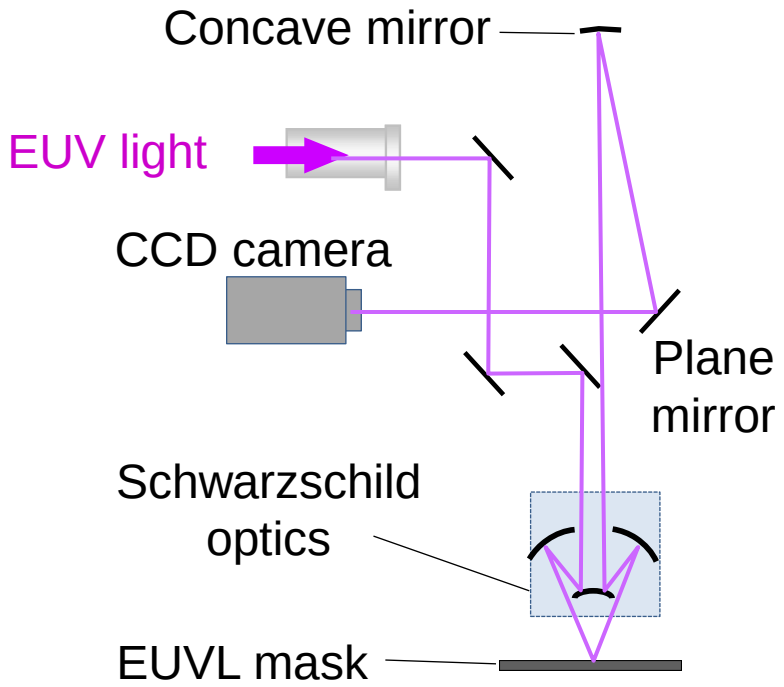
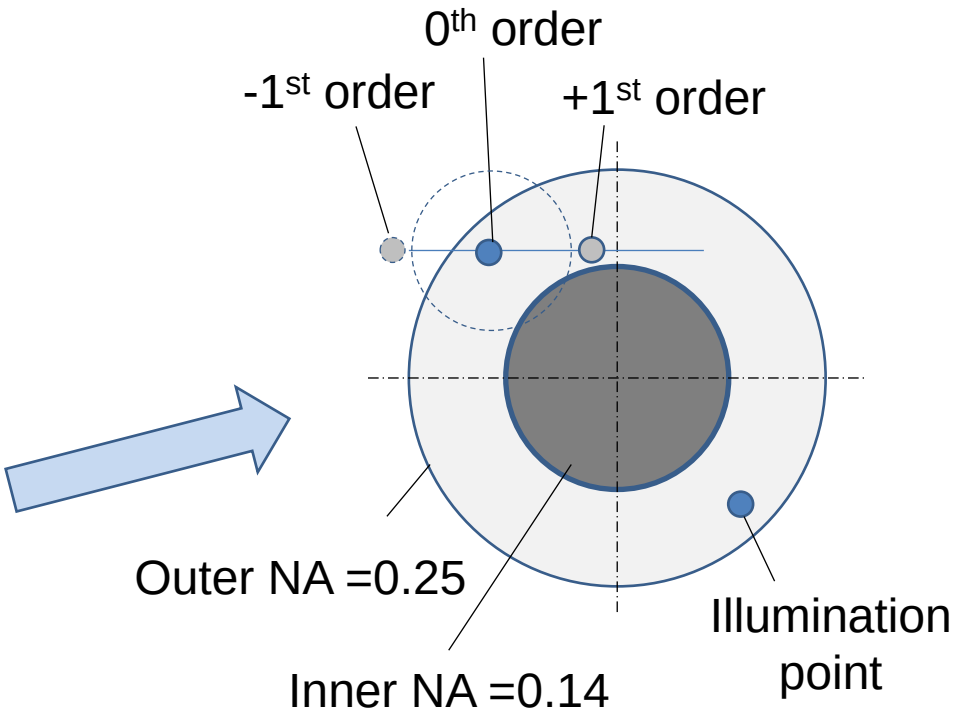
EUV microscope and the pupil of the optics.

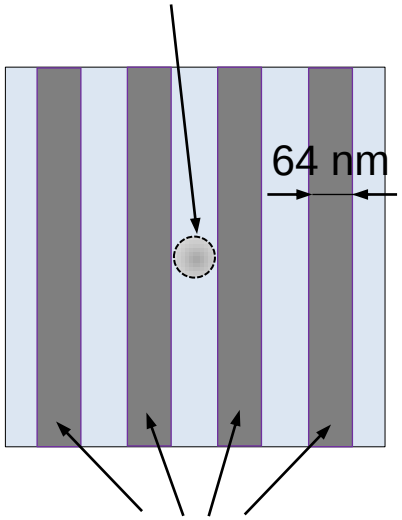
- Phase defect printability study for hp 16 nm ~ 11 nm generation.
- In collaboration with Tohoku University and University of Hyogo.
- Magnifying optics : Schwarzschild optics and concave mirror.
- Magnification :~1500 X.



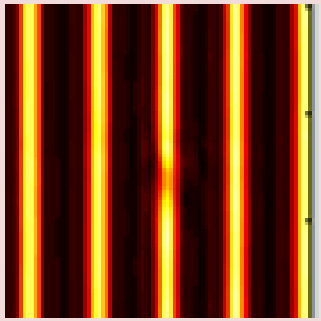
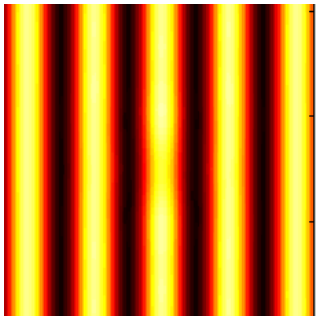
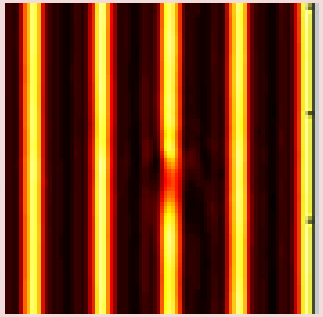
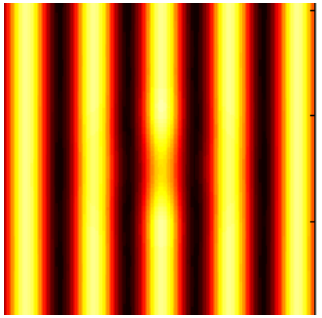


EUVL mask and its projected images

Bump phase defect
(FWHM=50 nm,
Height = 1.0 nm, 1.5 nm)



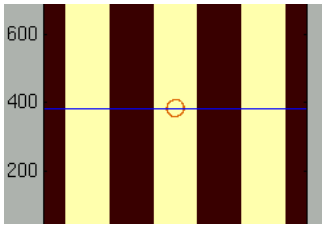
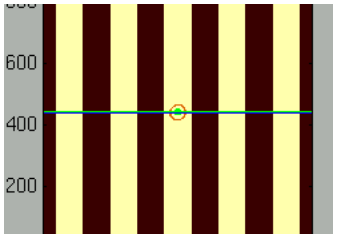
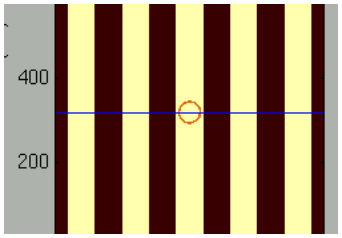
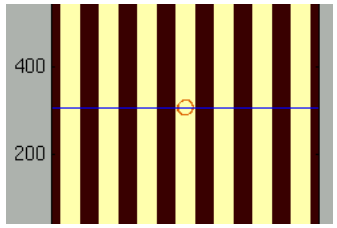
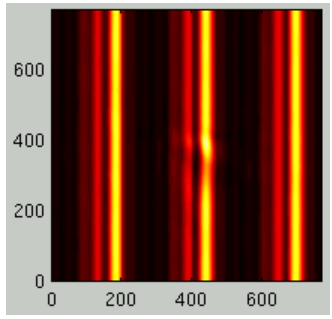
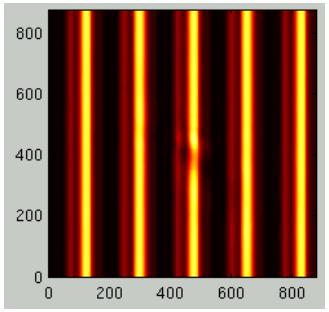
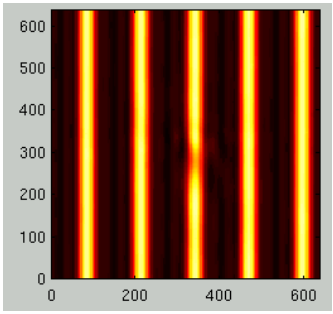
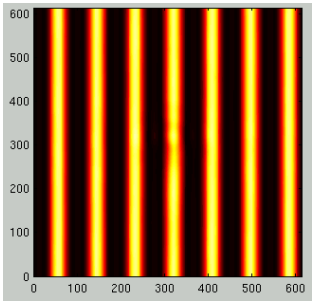
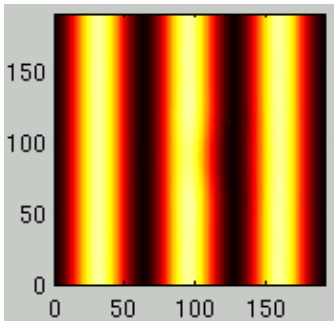
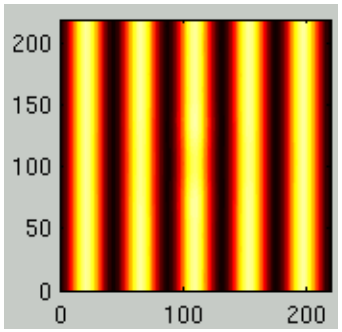
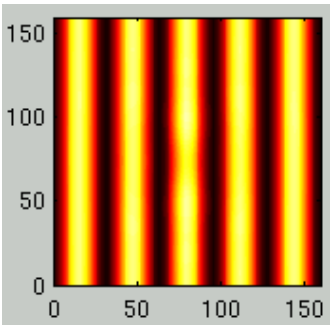
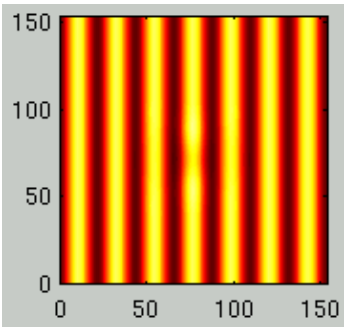
Absorber line patterns
（64 nm L&S)

	Microscope image NA=0.25/0.14 Off-axis mono pole illumination	Exposure tool image NA=0.33 Dipole illumination
	64 nm L&S @mask	16 nm L&S @wafer
FWHM=50 nm Height =1.0 nm		
FWHM=50 nm Height =1.5 nm		

EUV microscope can predict an influence of phase defect.

EUV Microscope image simulation

NA=0.25/0.14, Incident angle =13 degrees

	128 nm L&S at mask W=50 nm, H=1 nm	88 nm L&S at mask W=50 nm, H=1 nm	64 nm L&S at mask W=50 nm, H=1 nm	44 nm L&S at mask W=35 nm, H=0.8 nm
Mask pattern models				
EUV microscope observation images (NA=0.25/0.14)				
Exposure tool images (Dipole illum.) (Assumed NA)	 (NA=0.25)	 (NA=0.25)	 (NA=0.33)	 (NA=0.45)

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Summary

- Using aerial image simulation, the difference between the impacts caused by the same size bump phase defect and pit phase defect on 22 nm ~ 16 nm L&S projected patterns were analyzed.
- Phase defect printability for hp 26 nm ~ 22 nm line patterns was evaluated by exposure experiments and dependency of phase defect size and location was investigated.
- We have started a study of mask observation technique using magnifying optics. EUV microscope images can predict the existence of phase defect and a degree of its impact as an intensity variation of the images.

Future work

- Simulation prediction for hp 11 nm generation.
- Mask pattern observation using the EUV microscope

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Thank you for your attention.